6-4 Unconventional Superconductivity in Uranium Compounds

— Correlation between the Anomalous Electron Scattering and Superconductivity in URu_2Si_2 —

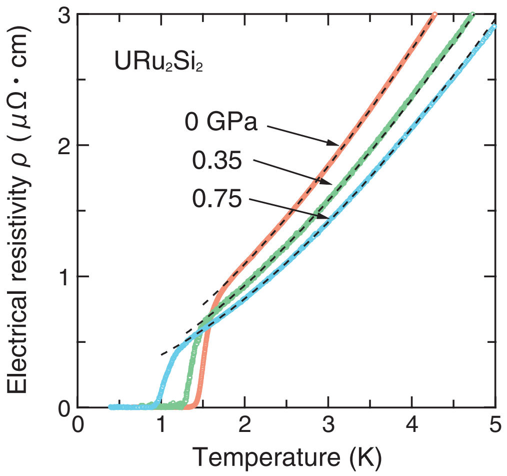

Fig.6-9 Temperature dependence of the electrical resistivity ρ in URu_2Si_2 at 0, 0.35, and 0.75 GPa

1 GPa corresponds approximately to 10000 atm. The steep decrease in ρ below 1.5 K is due to the superconducting transition in URu_2Si_2. The dotted lines show the results of fitting the data with the theoretical equation.

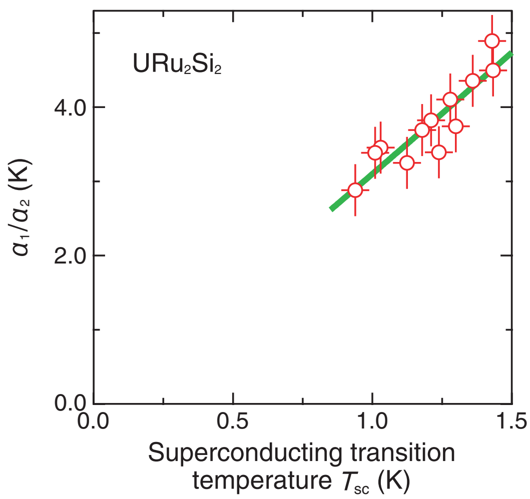

Fig.6-10 Analysis of the resistivity in URu_2Si_2 at high pressures

Relation between the superconducting transition temperature T_{sc} and α_1/α_2. The red line at each data point denotes the error bar.

Superconductivity (SC) is a macroscopic quantum mechanical phenomenon. In conventional metals such as lead, two electrons are bound together by lattice vibrations in the superconducting state; however, lattice vibrations may not play an important role in the formation of superconducting pairs of electrons in strongly correlated electron systems such as copper oxides or heavy fermion compounds. The physical properties of SC in these systems differ from those in conventional superconductors.

SC of the uranium compound URu_2Si_2 has attracted much attention because of the novel superconducting properties of URu_2Si_2. SC is strongly related to the electronic state of an unknown ordered phase. The nature of this ordered phase has not been determined for more than 25 years. The only information available is that symmetry breaking of the electronic state occurs in the ordered phase. This phase is known as "hidden order."

We measured the electrical resistivity ρ in URu_2Si_2 at high pressures, since the electronic property of the ordered state is reflected through the scattering of electrons. For example, the usual electron-electron scattering gives the T^2 term in the resistivity. We focus on the effects of pressure on the superconducting transition temperature T_{sc} and the electrical transport. As shown in Fig.6-9, the value of T_{sc} decreases with increasing pressure. We analyze the temperature dependence of ρ using the expression $\rho = \rho_0 + \alpha_1 T + \alpha_2 T^2$. We assume that ρ is the sum of the T-linear resistivity related to the unusual scattering of electrons and the usual T^2-term. We determine the pressure dependencies of α_1 and α_2 from the fit of the data with the expression, shown by the dotted lines in Fig.6-9.

α_1/α_2 and T_{sc} are suggested to have a linear relation, as shown in Fig.6-10. The pressure dependence of α_2 is very weak; hence, the value of T_{sc} depends primarily on the coefficient α_1. This suggests a strong correlation between and a common origin for anomalous electron scattering and SC. This finding is the basis for further studies on the hidden and SC states in URu_2Si_2.

Electrons in actinide compounds also exhibit many interesting physical phenomena. We will continue to search a new concept to understand these phenomena.

Reference

Tateiwa, N. et al., High-Pressure Electrical Resistivity Measurement on Heavy Fermion Superconductor URu_2Si_2 Using Super Clean Crystal, Journal of Physics: Conference Series, vol.273, no.1, 2011, p.012087-1-012087-4.